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Combined Use Of Radarsat-1 And AVHRR Data For The Identification Of Mesoscale Oceanic Features In The Campos Basin, Brazil

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Abstract Oceanic applications of RADARSAT-1 data include: (1) mapping mesoscale currents and regional circulation patterns; (2) identifying frontal zones, internal waves, eddies, meanders, upwelling, shears, and wind fronts. The investigated site includes coastal and oceanic areas of the Campos Basin, where oil production and fishery activities take place. Oceanographic dynamics is intense, with a pronounced interaction between the Brazil Current (BC) and coastal upwelling waters. The BC is a tropical, warm and saline water mass, characterized by low biologic productivity; coastal upwelling is characterized by cold water and high biologic productivity. In the interface between the BC and upwelling areas, mean flow instabilities give rise to mesoscale features (e.g., frontal zones, eddies, and meanders). Data from the AVHRR (Advanced Very High Resolution Radiometer) sensor are used as an aid to the interpretation of RADARSAT-1 images for coastal and oceanic applications. The combined use of simultaneously acquired AVHRR and RADARSAT-1 data greatly enhances SAR imaging capabilities for the identification of oceanic currents relevant to offshore operations. The AVHRR (1.1 km by 1.1 km resolution) data acquisition took place on 28 December 1997, about 07:02 p.m. local time. A RADARSAT-1 ScanSAR Narrow 1 ascending image was obtained in the same day, about 07:28 p.m. local time. The Unsupervised Semivariogram Textural Classifier (USTC) was used to enhance textural domains on the RADARSAT-1 image. These features, when combined with Sea Surface Temperature (SST) maps obtained from the AVHRR data, perfectly outlined coastal upwelling waters and the inshore BC boundary (characterized by strong thermal gradients). This remarkable result demonstrates that strong thermal gradients in the SST image are expressed as sharp roughness boundaries in the USTC-classified RADARSAT-1 data.

Keywords: Radar; oceanic applications; textural classification

1.0 Introduction

Thermal data obtained by the Advanced Very High Resolution Radiometer (AVHRR) installed onboard NOAA (National Oceanic and Atmospheric Administration) satellites have been successfully used for more than two decades to generate Sea Surface Temperature (SST) maps. Each day several AVHRR images are acquired over continent-sized areas. The oceanographic interpretation of temperature maps provides a synoptic view of the SST field and furnishes relevant information about the spatial and temporal evolution of upwelling, eddies, meanders and oceanic fronts.

Since the launching of Seasat in 1978, spaceborne synthetic aperture radar (SAR) systems have provided images of the oceans in a variety of polarization, wavelength, and incidence angle values. RADARSAT-1 is a sophisticated Earth observation satellite developed in Canada and launched on November 04, 1995. It is the first operationally-oriented radar satellite system capable of the timely delivery of large amounts of data. Possible oceanic applications of RADARSAT-1 data include: (1) mapping mesoscale (a few tens to a few hundreds of kilometers) currents and regional circulation patterns; (2) identifying frontal zones, internal waves, eddies, meanders, upwelling, shears, and wind fronts. However, RADARSAT-1 images have not been widely used for operational ocean mapping and monitoring in tropical regions of the world. A multisensor approach can potentially improve the utilization of RADARSAT-1 data in mesoscale ocean studies in these areas. Interpretation of oceanographic features can be strongly supported by the joint analysis of SST maps derived from AVHRR data and simultaneously acquired radar images (Johannessen et al.,1994).

In this study, AVHRR images were obtained in the Campos Basin as close as possible to the time of RADARSAT-1 data acquisition. The Unsupervised Semivariogram Textural Classifier (USTC) was used to enhance textural domains on the RADARSAT-1 image. Our objetive is to assess if the combined use of AVHRR-derived SST maps and USTC-classified RADARSAT-1 images increases SAR imaging capabilities for the identification of mesoscale oceanographic features.

2.0 Oceanographic Characteristics Of The Study Area

The investigated site includes coastal and oceanic areas of the Campos Basin, south-east Brazil, where oil production and fishery activities take place (Fig. 1). Oceanographic dynamics is intense, with a pronounced interaction between the Brazil Current (BC) and coastal upwelling waters. The BC is a tropical, warm (>25°C) and saline (>36 PSU) western boundary current, characterized by low biologic productivity. Its flow is oriented from NE to SW all year round in the region. Boundaries and mean velocities of the BC do vary seasonally. The presence of meanders and mesoscale vortices can also introduce large changes in the flow. Coastal upwelling is characterized by cold water and high biologic productivity. Upwelling in the coastal areas of Cabo de São Tomé and Cabo Frio (Fig. 1) was portrayed by Kampel *et al.* (1997) e Silva Jr. *et al.* (1997) using AVHRR images. In the interface between the BC and upwelling areas, mean flow instabilities give rise to mesoscale features (e.g., frontal zones, eddies, and meanders). Thermal contrast between warm BC waters and cold upwelling waters occurs mostly during spring and summer. Therefore, the combined use of AVHRR and RADARSAT-1 data acquired within such a time frame is appropriate to identify and map these mesoscale oceanic features.

2.1 Remote Sensing Data And Derived Products

The Advanced Very High Resolution Radiometer (AVHRR) is a five channel sensor that acquires one visible band (band 1) used to identify clouds; one reflected infrared band (band 2) used to separate land and water; and three thermal infrared bands (bands 3, 4, and 5) used to map the sea surface temperature. All bands have a nadir spatial resolution of 1.1 km (Sabins, 1997). AVHRR data were processed in this study for the generation of a Sea Surface Temperature (SST) map (Fig. 2). One of he NOAA algorithms (Kidwell , 1995) was used to convert brightness temperatures into atmospherically corrected SST values. The AVHRR image was obtained as close as possible to the time of RADARSAT-1 data acquisition (Table 1).

TABLE 1: Acquisition schedule of remote sensing data

Remote Sensing Data	Orbit	Acquisition Date	Time (local)
AVHRR/NOAA-12	Ascending	28 Dec 1997	07:02 p.m.
RADARSAT-1 ScanSAR Narrow-1	Ascending	28 Dec 1997	07:28 p.m.

A RADARSAT-1 image in the ScanSAR Narrow 1 (SCN1) beam mode was used in this investigation (Table 1). Each RADARSAT-1 SCN1 image has a nominal area of 300 km x 300 km at an approximate resolution of 50 m; incidence angles positions range from 20° to 40°. The Unsupervised Semivariogram Textural Classifier (USTC) was applied in this study to RADARSAT-1 SCN1 data in order to enhance mesoscale ocean surface features. It is a deterministic classifier, which provides the option of combining both textural and radiometric information (Miranda et al., 1997). Radiometric information is conveyed by the despeckled digital number (DNdsp) value. The speckle noise reduction algorithm used was the adaptive median filter. Textural information is described by the shape and value of the circular semivariogram function.

3.0 Results

The AVHRR image of the study area was acquired with 8 % of cloud cover. Therefore, the SST map

derived from it adequately portrays mesoscale oceanic features in this portion of the Campos Basin (Fig. 2). The SST range of the BC was 25°C-28°C; shelf waters varied from 23°C to 24°C and upwelling waters from 20°C to 22°C. When the BC stretched south of parallel 22°S, it developed a cyclonic eddy (clockwise in the Southern Hemisphere) with diameter of approximately 70 km. This eddy contained warmer water (26°C) than the surroundings (25°C). It can also be noted that colder (20°C to 22°C) subsurface water is upwelled south of Cabo de São Tomé moving away from the coast towards the south. A 135-km long profile extending from the axis of the BC to the coastal region of Macaé is shown in Fig. 3. It includes the transition between the inshore front of the BC to the southeast and upwelling waters of Cabo de São Tomé to the northwest. The maximum horizontal temperature gradient found along this profile is about 0.17°C km^{-1} (5°C variation in 28.33 km).

The RADARSAT-1 SCN1 scene (Fig. 4) was obtained on 28 December 1997, 26 minutes after the NOAA AVHRR image (Table 1). The USTC-classified RADARSAT-1 SCN1 image (Fig. 5) portrays prominent textural features with configuration and orientation that are in good agreement with the SST map (Fig. 2). These textural features perfectly outline (a) coastal upwelling waters of Cabo de São Tomé and (b) strong thermal gradients that characterize the inshore front of the BC. Such a result demonstrates that strong thermal gradients in the SST image are expressed as sharp roughness boundaries in the USTC-classified RADARSAT-1 data.

4.0 Conclusions

Textural features identified on the RADARSAT-1 SCN1 image of the Campos Basin using the Unsupervised Semivariogram Textural Classifier (USTC) perfectly outline mesoscale oceanic features identified on the Sea Surface Temperature (SST) map obtained from the AVHRR data. This result demonstrates that RADARSAT-1 and AVHRR manifestations of, respectively, surface roughness and sea surface temperature can be compared in the study area, since strong thermal gradients in the SST map are expressed as sharp roughness boundaries in the USTC-classified RADARSAT-1 data.

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FIGURES

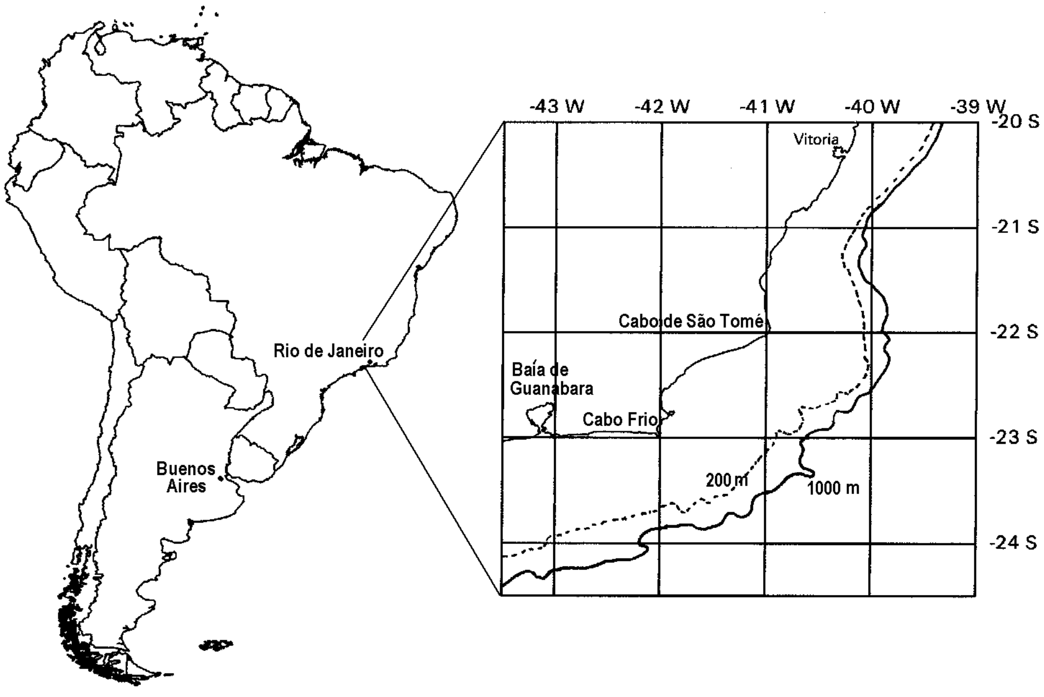

Fig. 1: Location map

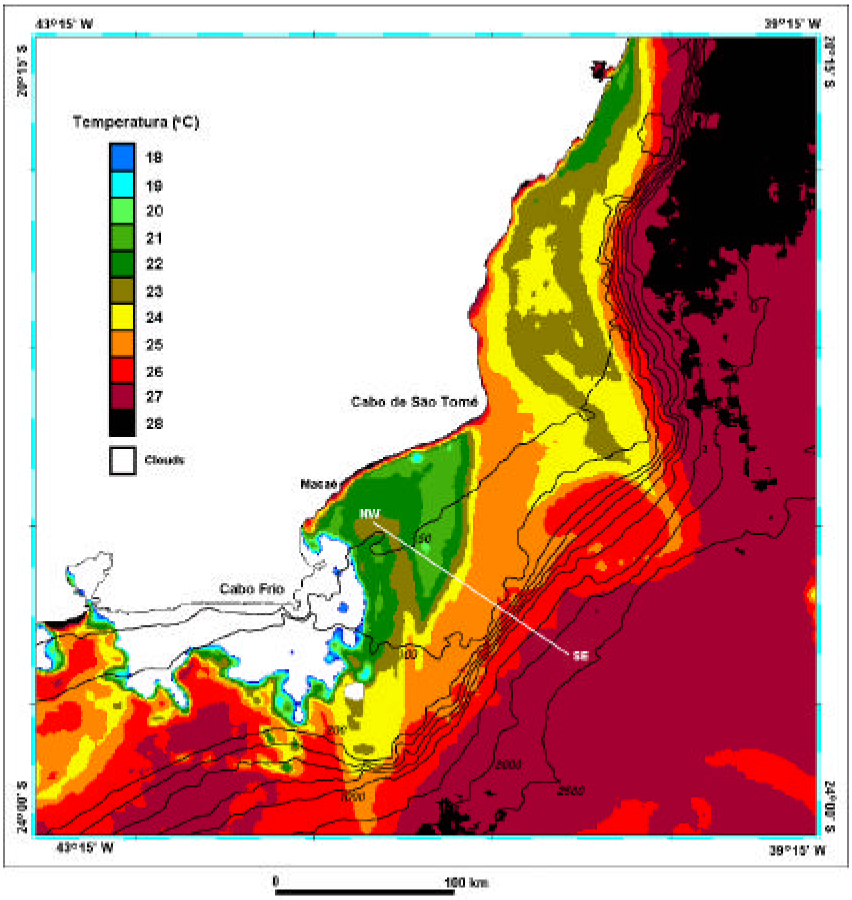

Fig. 2: Sea Surface Temperature (SST) map derived from AVHRR/NOAA-12 image.

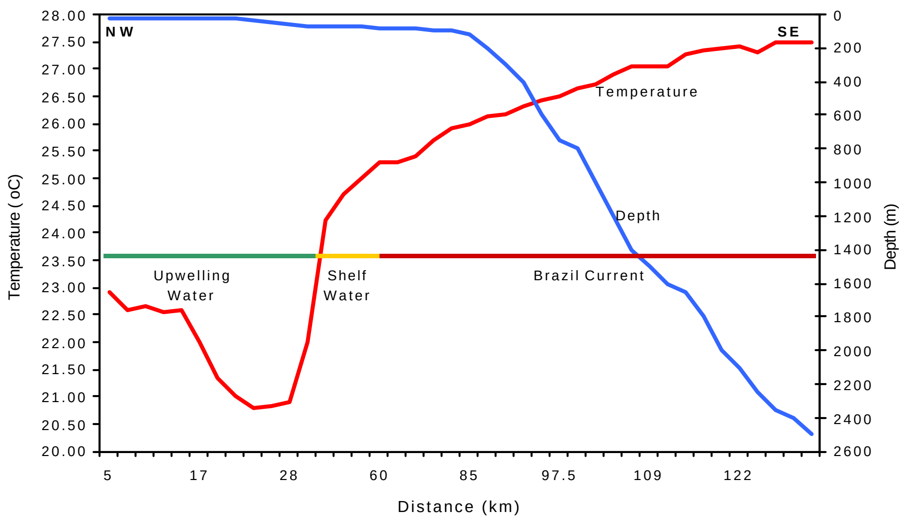

Fig. 3: Macaé profile (see Fig. 2 for location) showing the horizontal variation of sea surface temperature.

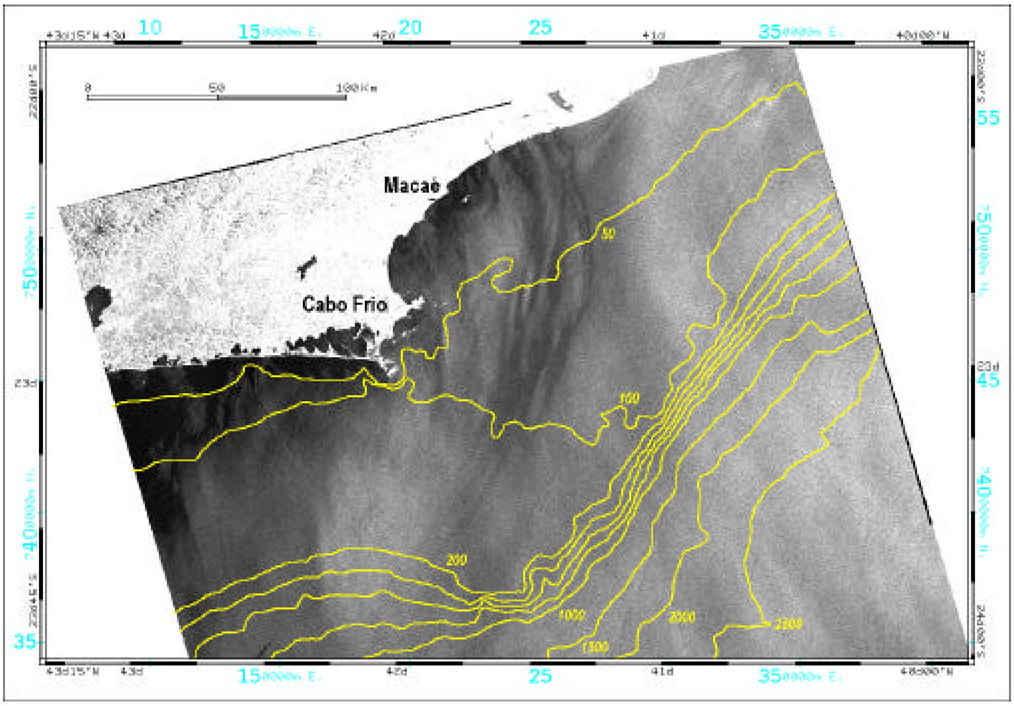

Fig. 4: RADARSAT-1 SCN1 image with bathymetry (meters) offshore Cabo Frio and Macaé.

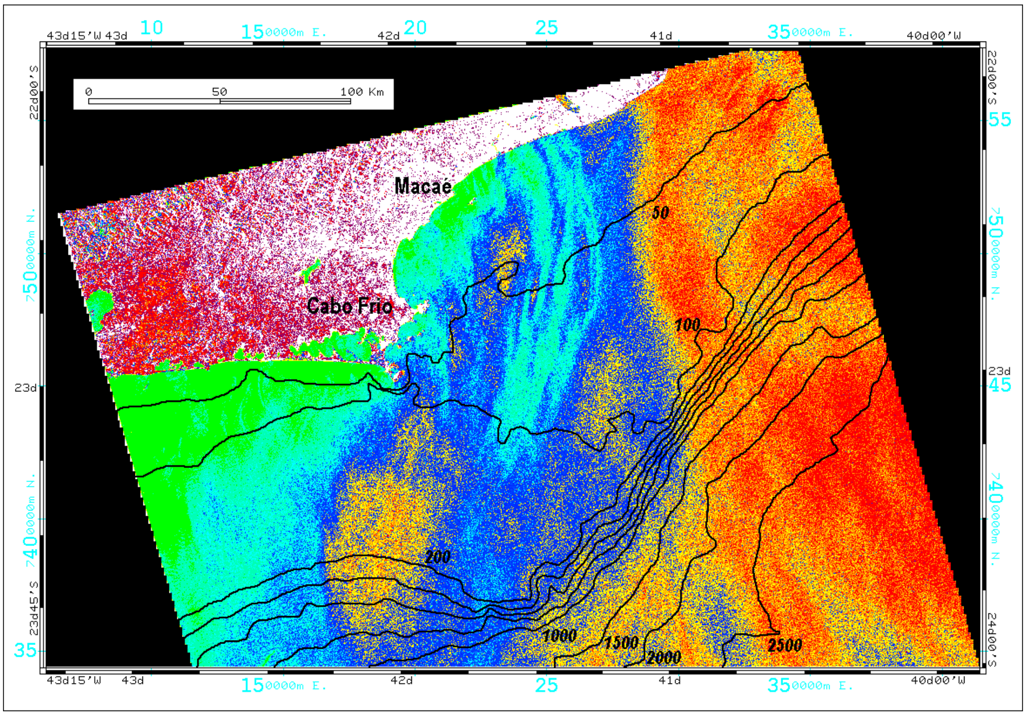

Fig. 5: USTC-classified image with bathymetry (meters) offshore Cabo Frio and Macaé.